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NATURAL REPRODUCTION IN THE WESTERN WHITE PINE TYPE PROGRESS REPORT SUMMARIZING INVESTIGATIONS TO DATE

By

Robert Marshall

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By Robert Marshall
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I

INTRODUCTION

The purpose of the reproduction study conducted by the Northern Rocky Mountain Forest Experiment Station in the western white pine type is to understand the factors affecting the re-establishment of the forest through natural reproduction following the partial or complete destruction of the old stand by logging or fire.

It seems desirable to mention briefly the practical importance of such a reproduction study. In any forest type the best silvicultural system depends primarily on which system gives most reproduction. To get this information, an inventory of old timber sales is not enough, because such an inventory only gives us a statistical statement of what has happened but entirely overlooks causes, which alone give us an adequate basis for predicting what will occur. Therefore, it is essential to get behind the mere fact that reproduction has been good or bad, and apprehend the causes which have given rise to one or the

other quality of reproduction. With such knowledge, we should ultimately be able to select with a high degree of dependability the best silvicultural system possible on any site.

Reproduction studies have been intermittently conducted by the Northern Rocky Mountain Forest Experiment Station for 17 years. It cannot be said that any very large or permanent truths have been established in that period. In Newton's words, we have merely found here and there "a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before us." Nevertheless, these occasional pebbles and shells which have been unearthed, though not final--and it remains a question whether any truths are ever final--at least form the best existing expression of the fundamental influences which control natural reproduction in the western white pine type. It is the purpose of this report to summarize this knowledge gained in the reproduction studies to date.

In detailing the results thus far obtained the material will be presented under four major headings:

1. Seed production
2. Seed dissemination
3. Germination
4. Survival

Each of these divisions forms a distinct step in the regeneration of any stand which has been altered by fire or logging.

Before closing this introduction it is important to point out that the author merely happens to be the man at present in

charge of the reproduction study. In the course of this report recognition will be given to those men primarily responsible for individual experiments, but aside from this specific acknowledgment it is desirable to mention at the beginning those whose ideas and execution of work, inadequately accounted for by the mere citation of the published results of their efforts, have played an important part in the development of our knowledge of western white pine reproduction. First, should be mentioned the author's predecessors in charge of the natural reproduction studies: D. R. Brewster (1911-1917), and J. A. Larsen (1917-1924). Next, special mention should be made of all the contributions of R. H. Weidman, not only in his capacity as Director of the Station for the past seven years, but more specifically through his work in the methods-of-cutting study of which he has direct supervision. Gerhard Kempff, resident Forest Officer at the Priest River Branch of the Experiment Station from 1918 to 1928, through a uniquely intimate knowledge of the western white pine type and a large amount of conscientious field work, has contributed greatly to almost every phase of this project. Furthermore, it is important to acknowledge the sound ideas and painstaking work of many of the men who have assisted in the field, especially J. V. Hofmann, J. H. A. Grossman, and H. T. Gisborne of the permanent staff, and T. S. Hansen, Alden B. Hatch, Clarence Averill, and C. W. Waters of the temporary assistants. The advice or active research of certain Regional Office men has also been of great value, especially that of R. Y. Stuart, F. I. Rockwell, F. A. Silcox,

W. C. Lowdermilk, Elers Koch, and D. S. Olson.

II

SEED PRODUCTION

The first work ever done at the Experiment Station dealt with seed production. In the autumn of 1911, Raphael Zon (18) made a study of the seed borne in four different stands of the western white pine type. His method was to lay out half-acre sample plots on which all the timber was tallied, and then to fell representative trees, collect their cones, and extract, count and germinate the seed. Among the more interesting of the tentative conclusions which he formulated were the following:

1. The dominant and codominant trees produced 98% of all the western white pine seed in 1911.
2. Normally stocked stands yielded from 75,000 to 150,000 germinable western white pine seeds per acre in 1911.
3. The younger stands from 72-100 years produced a larger quantity of germinable seed than the older trees.

The general conclusion in regard to production by the two upper crown classes has been checked by recent examinations of the cone-crop production on permanent sample plots. This has shown that only an occasional intermediate western white pine bears any cones, while there is not a single record of a suppressed tree of this species with a seed crop.

No further information has been gathered on the seed production of stands. However, some interesting figures have been obtained by D. S. Olson on the maximum cone production of individual trees. He has found single white pines yielding 75,000 germinable seeds; yellow pines, 360,000 seeds; cedars, 700,000 seeds; white fir, 28,000 seeds; and alpine fir, 57,000 seeds.

Little is known concerning the effect of age of trees on seed production. The third of Zon's conclusions has some bearing on the subject. Olson has started a study of the effect of age on the germinative vigor of white pine seeds. In regard to the minimum age of production, Larsen and Lowdermilk (14) found mature cones on 17-year-old trees near upper Priest Lake. They suspected that the reproduction on a double burn was due to seed scattered by a 20-year-old stand.

The subject of the relation between mechanical injury and seed production opens an interesting field. It is a well known physiological fact that severe injury often stimulates fruit production in plants. Therefore, the phenomenon noted in one stand in which some of the large defective hemlocks were girdled is not surprising. It was observed that out of 322 trees of eight different species, the only ones on the entire area with good seed crops were seven girdled hemlocks. Only sixteen hemlocks were girdled in all, so that nearly half bore good seed

crops, whereas out of the other 306 trees on the plot not a single one could be placed in this category. These results were obtained 1½ years after girdling.

In contrast to this situation, a study of three 1926 burns showed no correlation between the severity of fire damage and the cone crop borne on the injured trees one and two years later.

One bit of information in connection with seed production which it is important for the silviculturist to know is at what interval good seed years come. In western white pine we have a fairly adequate basis of knowledge in this connection dating back to 1910. From the records in the Office of Planting, it appears that good seed years have occurred regularly at three-year intervals and have included 1911, 1914, 1917, 1920, 1923, and 1926. Bumper crops were provided in 1911 and 1923. The year 1919 at the other extreme was a complete failure. Not a single western white pine cone was observed in the whole Priest River Valley, and only a few anywhere else in the northern Rocky Mountain region.

But all general observations in regard to seed production are of necessity too crude to be of great value. What really seems needed is a definite quantitative statement of the amount of seed shed per acre in

different years by stands of different ages. A start has been made during the past season to obtain this information. Sixteen seed traps have been layed out mechanically in 75 and 300-year-old stands. These traps take the form of boxes with 16-mesh wire cloth underneath, through which the finest seeds cannot fall, and with two-mesh wire cloth on top, which permits the entrance of all seeds but prevents birds and rodents from eating them. Between the two screens is a space of 6 inches. Each box has a surface area of 1/4000 of one acre. They are concentrated on half-acre plots on which the size and crowns of all the trees have been described. It is planned to keep these traps in place for 50 or 100 years. By counting the catch and by running germination tests of the seeds collected in the traps each year, it should be possible to determine the amount of seed shed per acre for every species, the bearing of advancing age on amount and viability of seed production, the nature of seed cycles, the effect of climate, and the frequency of good and poor seed years.

One unknown but very vital characteristic of western white pine seed production is whether white pines which have been girdled by fire will mature the seed crop which is only partially ripe at the time of girdling. There was fairly good deductive evidence that

this was the case, but the only way to be sure of the matter was to actually do some girdling. For this purpose four groups of three trees each were girdled by blow torch at the Priest River Branch of the Experiment Station on June 15, July 1, July 15, and August 1. It was planned to collect the cones of these trees just before maturity and run germination tests. Unfortunately, a couple of days before the cones were to be gathered, all but one wormy cone were cut down by squirrels. The test will probably be repeated in the near future, perhaps under the protection of an armed guard.

Eventually a study more fundamental than any of these will be needed touching on the factors, internal and environmental, which control the development and fertilization of the flowers, and the setting and maturing of the fruit. All these processes must take place before a single seed is ripened and disseminated. It is only through a thorough knowledge of them that we can understand adequately the subject of seed production.

III

SEED DISSEMINATION

Seed dissemination occurs at three different periods in relation to the metamorphosis of any stand by fire or logging. First, it may occur before the metamorphosis, seed being collected in the duff or a virgin stand for one to many years prior to any disturbance. This method of providing an area with seed will be referred to as antecedent dissemination. When this seed has been in the ground two or more years it is called stored seed, but such a term does not apply when it merely holds over in the ground for one year, since this is a normal condition. Second, seed may be shed during the same season the metamorphosis takes place. This occurs when fire destroys a stand just before the maturity of the seed, which is shed a short time later on the fresh ashes. It may also occur when an area is logged at the same time or shortly after the cones open. Such a seed source will be referred to as coincident dissemination. Third, seed may be shed after fire or logging has altered the original stand. This may either take place from seed trees scattered on the area or from groups of trees left standing to one side. Such a seed source will be referred to as subsequent dissemination. These three methods of dissemination through an antecedent, coincident and subsequent seed source will be considered separately.

Antecedent Dissemination

In the early days of forest research in the northern Rocky Mountains, a great deal of emphasis was placed on the stored-seed theory. This held that the principal source of seed for reproducing an area was that which had been collecting in the duff for years prior to fire or logging. It seemed like a ready panacea to solve all the reproduction problems. In fact it was so brilliant an hypothesis that carefully gathered data were bent into strange forms in order to support the devious pattern of this theory. Later work has indicated that a great many fallacies were involved in these specious deductions. Nevertheless, it seems worth while to mention them as an essential historical background for our present ideas.

The stored-seed theory was first conceived by J. V. Hofmann in 1912. Its initial support was an analytic study of two large, partially burned, clear-cut areas. It was found that by far the best reproduction was obtained on those portions which were unburned, while the severely scorched surfaces showed a distinctly lower total of seedlings than the lightly-burned terrain. Thus it seemed apparent that some factor other than seed trees must have played a part in controlling the reproduction.(3)

A later study conducted by Larsen (11) along

the same lines gave similar results. The best reproduction was found to occur where the duff was either unburned or lightly burned. Most of the germination took place the first summer after logging.

There were two great weaknesses to these studies. First, they rested on a very meager basis of field data. Second, no consideration was given to the possibility that the scarcity of reproduction on the burned surfaces was due to the occurrence of fire immediately following an exceedingly good seed year. As a matter of fact, that was precisely what happened. Both 1911 and 1917 provided prolific cone crops and the ground was abundantly sown. But before there was a chance for germination or development the ground was denuded by logging and burning. Wherever the fire ran severely all seed was, of course, destroyed; where it burned lightly a few escaped, while where it did not touch there was abundant germination. This, however, was not attributable to true stored seed, but merely to a one-year holdover of coincident dissemination on spots where the duff escaped destruction.

This effect of fire on coincident dissemination was more clearly illustrated recently on a sample plot in Squaw Valley. Here it was found that out of a total of 143 western white pine seedlings only two occurred

on areas which had been burned. The old line of reasoning would have proclaimed that this was a sure proof of the stored-seed theory. However, the brush was consumed on this area at the very beginning of October, 1926, after the dispersal of an abundant western white pine seed crop. Consequently, all the white pine seed on the scorched spots was destroyed. The same was true of larch and white fir, which one year later showed respectively only two out of thirty-seven and two out of sixty-one seedlings to have occurred on the burned area. On the other hand, hemlock and cedar, which are late shedders, showed 180 out of 815 seedlings on the burned area in the one case and 10 out of 31 in the other. This example emphasizes the fact that the mere absence of seed on burned areas does not signify that the principal seed source is stored seed.

There was another experiment which both Brewster (4) and Larsen (10) performed, which was used as one of the strongest pillars to support the stored-seed theory. In 1915 and again in 1918 different samples of duff were recovered from the virgin stand; the western white pine seeds were sifted out; and germination tests were made. In the earlier experiment, the number of viable seeds obtained per acre varied from 877 to 5,260. In

the latter test an average of 5,456 western white pine seeds were recovered per acre. From these figures it appeared that stored seed played a very important part in reproducing western white pine stands. But there was an entire failure to consider the fact that each exhumation of the seeds was made immediately after a good seed year, and that the seeds recovered merely represented the normal holdover of western white pine seeds which is such an annoyance to every nursery man.

Before leaving the purely deductive side of this matter it would be well to mention some recent negative evidence which tends to discount the importance of the stored-seed theory. Larsen (13) in his 1923 study of old burns found very little reproduction which had originated during the first two years following the 1910 fires. Yet stored seed would mainly germinate, if at all, immediately after the opening of a stand. Haig (7) concluded, after studying six old timber sales in 1925, that the bulk of the reproduction on these cut-over areas came from seed trees. His reason lay in the fact that in the majority of cases over half the young growth started 7 or more years after cutting. Marshall determined, through the examination of over 500 milacre quadrats, that the best reproduction following the 1926 fires came where the duff, and with it all possible stored seed, had been destroyed. For instance,

on one area near Tillicum Creek on the Kaniksu National Forest, about 15,000 western white pine seedlings per acre were found where the duff had been completely consumed; whereas only 3,500 seedlings occurred where it was unburned. Thus it would appear that even if stored seed is of some importance, its significance is completely overshadowed by other factors which permit vastly more reproduction on surfaces where all the stored seed has certainly been destroyed.

If, as this recent evidence seems to infer, stored seed is normally much less important than coincident and subsequent dissemination, it should be apparent in studying the seed coats of the seedlings which germinate following logging or fire. Such a study was conducted on the sample plot at Tillicum Creek. A search was made for the coat of every western white pine seedling. Out of 853 coats, 529 were recovered, and not a single one of them showed the remotest evidence of having been through the fire. In other words it appeared that all of the abundant reproduction on this area, averaging 11,500 western white pine seedlings per acre, must have been attributable to coincident dissemination.

But everything mentioned so far has been in the deductive field of investigation. There are quite a number of experimental tests which have yielded or

promise to yield more specific results. One, on which special emphasis has been laid, was initiated in the spring of 1927. It has involved the establishment of sets of twin quadrats the spring following fire and logging. One quadrat has been covered over with 12-mesh wire cloth fine enough to keep out all seeds of the western white pine type except the smaller hemlock and larch seeds. Under this cloth we know that all future germination must be attributed to stored seed or coincident dissemination, since subsequent dissemination from seed trees will be effectively precluded by the screening. Next to each screened quadrat, on as nearly an identical site as possible, an unscreened quadrat has been laid out. Here the reproduction obtained will be due not only to stored and coincident dissemination, but also to subsequent dispersal. By comparing the results under the two sets of conditions it should be possible to obtain a comparative figure on the importance of stored seed as compared with seed-tree disseminated seed.

Of course, it is recognized that the mere fact of placing the screening alters site conditions. A careful check by soil thermometer has shown that in normal weather the screening has very little effect on soil temperature, but that on critically hot days when the temperature in the top quarter inch of soil

rises to 90° or more, screened quadrats will run from 2°F. to 18°F. cooler than the unscreened ones. This, no doubt, has an important effect on survival. However, in this experiment we are not interested in survival but in germination, it being assumed that there will be no difference in the former characteristic between antecedent, coincident, and subsequent dissemination. The question, therefore, arises whether these screens affect germination and this seems very unlikely, since germination takes place before it becomes hot enough for the screens to alter the site.

Although the most valuable results of this test will not turn up for several years, the very first year has brought out some interesting developments. Table 1 shows a comparison between the reproduction per acre on the screened and unscreened quadrats two years after the fire. The figures, based on 247 pairs of quadrats, indicate that there was virtually as much western white pine reproduction under the screens as in the open. This signifies the importance of the characteristic one-year holdover in western white pine seed. However, no germination under the screens can be considered as genuine stored seed until at least one more year has elapsed.

TABLE 1

REPRODUCTION ON OPEN AND SCREENED QUADRATS

TWO YEARS AFTER FIRE -- 1928

Species	Number of Seedlings Per Acre	
	Open Quadrats	Screened Quadrats
White Pine	1,296	1,036
Western Larch	101	0
Western Hemlock	43	0
Red Cedar	65	144
White Fir	4	4
Douglas Fir	0	0

The other species exhibit only a small amount of germination in either sort of quadrats. Curiously enough the only species which show a marked deficiency in germinations under the screen as contrasted with the other are larch and hemlock and these are the two whose seeds are too fine to be excluded by the 12-mesh cloth.

In all open quadrats birds and rodents probably cause a small decrease in the total reproduction as contrasted with the screened quadrats.

One further step in this screening experiment is required in order to isolate completely stored seed. In the present experiments the screened frames were all laid down after fire or logging, and thus coincident dissemination also had a chance to be effective. What is needed is to screen off areas prior to logging or fire so that the only possible seed source will be the antecedent one. This has been done during the past summer in the case of a logging operation, but the opportunity has not yet come for screening off quadrats in front of a going fire.

In order to complete our picture of the stored-seed theory, it is necessary to determine certain fundamental facts. How long will stored seed survive? What heats must they be able to withstand to live

through a fire? Unless we can answer these questions, we cannot be sure of any stand we take in regard to stored seed.

Two types of storage tests have already been inaugurated. One of these was started 17 years ago. Seeds of the different species common in the western white pine type, collected from 1910 through 1919, were placed in sealed bottles. These were stored in a house subject to temperature fluctuations from about 0°F. to 80°F. During 1928 these seeds were subjected to germination tests to determine how time had affected their viability. The results are shown in Table 2. The most striking point brought out is the high per cent of viability among practically all the samples of yellow pine seed. Those gathered on the Bitterroot in 1912 demonstrate this quality to the greatest degree. Two years after collection a germination test of this seed showed a viability of 32.7%; 8 years afterward the result was 33.3%; and 15 years later it was 33.0%. The viability of lodgepole pine has also held up very well over a period of 18 years, but none of the other species of the western white pine type show any significant amount of germination even when the period of storage has been as short as 9 years.

TABLE 2

GERMINATION OF SEEDS STORED IN BOTTLES

Species	Year Collected	Locality	Original Germination Per Cent	Germination Per Cent 1928
Western Yellow Pine	1911	Colville N.F.		29.6
Western Yellow Pine	1911	Whitman N.F.		12.0
Western Yellow Pine	1912	Kaniksu N.F.		7.6
Western Yellow Pine	1912	Bitterroot N.F.	32.7	33.0
Western Yellow Pine	1915	Bitterroot N.F.	32.5	14.2
Western White Pine	1911	Kaniksu N.F.		0.8
Western White Pine	1914	Kaniksu N.F.	32.0	0.0
Western White Pine	1915	Kaniksu N.F.	36.4	0.0
Lodgepole Pine	1910	Beartooth N.F.		15.6

No germination was obtained from four lots of Douglas fir, three lots of western larch, three lots of western red cedar, two lots of lowland white fir (Abies grandis), one lot of white fir (Abies concolor), one lot of alpine fir, one lot of Engelmann spruce, and one lot of western hemlock. These lots were collected between 1912 and 1919.

In each case 500 seeds were tested.

The bottles in which the seeds were stored were closed but not sealed.

Of more direct significance are the field-storage tests, because these simulate the conditions actually found in nature. As early as 1915 Brewster (4) stored 210 baskets containing duff and western white pine seed in the soil of the virgin forest with the object of finding out how long such seeds would remain viable. Unfortunately the baskets created such an unnatural condition that mold got into all of them and ruined the experiment. A similar fate awaited Larsen's test of three years later, but in 1920 a more successful one was started. It yielded results not wholly free from the suspicion of external influence, but it seems worth presenting the figures which he obtained. One year after sowing 1,000 seeds in the duff it was found that 20.0% remained viable; 2 years later only 1.3% could be made to germinate; after three years the percentage jumped unaccountably to 32.7%; but after the fourth and fifth years there was no germination whatever. Nothing could be found to explain the eccentric results of 1922 and 1923. From this one test it would appear that reproduction from seed stored in the duff more than three years is negligible, but the evidence is entirely insufficient for any definite conclusions.

Larsen's line of attack seemed to offer, however, a proper solution to the problem and in the

fall of 1927 it was resumed on a more ambitious scale. Eight different duff beds were subdivided into 8 sub-beds each. One sub-bed was sown to each of the following species: western white pine, western larch, Douglas fir, white fir, red cedar, and Engelmann spruce. Two sub-beds were reserved as checks on the amount of seed naturally stored in the duff. Each of the eight beds was then screened over with 16-mesh wire which lay flat on the ground and was buried at the edges. This will preclude all further seeding and keep out rodents. One of these beds will be exhumed each year for eight years to come. The seed will be sifted and germination tests made for each species. It is realized that many variable factors are involved in tests like this. A large influence is probably exerted by the climate immediately following sowing, and by the site on which the study is conducted. Consequently it is planned to sow numerous beds in different years and on varied sites.

The second fundamental point which must be studied in connection with the stored-seed theory involves the temperatures which it is necessary for seeds to withstand if they are to survive fire. In other words, how hot does the duff in which the seed is stored become under different intensities of

burning? It was one of the cardinal principles of the old stored-seed theory that seeds could live through all but extremely heavy burns in large enough numbers to adequately reproduce fire-swept areas. But no one had any idea what temperatures this implied that seeds would have to endure. In order to obtain this information the Northern Rocky Mountain Forest Experiment Station has measured by means of a thermo-electric pyrometer the temperature under actual fires. It has not merely seemed enough to find out the maximum temperatures, but it has also appeared important to determine how long killing temperatures have been protracted. Twenty tests in light, medium and heavy burns have already been made and the results are summarized in Table 3.

TABLE 3

TEMPERATURES UNDER DIFFERENT INTENSITIES OF BURN

Intensity of Burn	Top of Duff			Between Duff and Humus			Between Humus and Mineral Soil		
	Max. Temp. Degrees Cent.	Hours and Minutes above 60°C.	Hours and Minutes above 100°C.	Max. Temp. Degrees Cent.	Hours and Minutes above 60°C.	Hours and Minutes above 100°C.	Max. Temp. Degrees Cent.	Hours and Minutes above 60°C.	Hours and Minutes above 100°C.
Light	523	1:58	1:32	235	1:14	0:28	74	0:52	0
				106	2:06	0:04			
	524#	1:34	1:12	67	0:48	0:00			
	534	2:12	1:56	150	1:04	0:22	79	0:56	0
							65	0:22	0
	586	1:54	0:18	180	1:46	1:04	74	0:52	0
				207	1:48	0:54			
	731	0:58	0:40	97	0:54	0:00	83	0:52	0
Medium	737#	6:00	4:30	216	6:00	4:00			
							281	3:20	1:46
Heavy	591	9:42	7:20	518	9:38+	9:04+	499	9:32+	9:04+
	595						187		
	672	12:00	7:48	336	22:00+	15:00+	161	22:00+	4:35+
				442	12:16	8:58			
	676								
	885						468		
				245	7:34	3:16			
				336	7:42+	6:00			
				391	7:50+	6:06+			
				420	8:00	5:56			

Tests in which seed was actually sown ahead of fire.

\+ Indicates that temperature was still above 60 or 100 degrees when test was discontinued.

From this table it would appear absolutely impossible for seed to live through a heavy or medium burn. Not only are the maximum temperatures from 591 to 885 degrees centigrade at the top of the duff and from 216 to 518 degrees at the bottom certainly fatal to tree seeds, but in addition, the protracted periods that the temperatures remain above 60°C. and 100°C. would probably cause complete mortality even without the extremes. In light burns the surface temperatures are also entirely too high for any survival. In a few cases, however, it seems possible that at the very bottom of the duff it might be cool enough for seeds to pull through. The temperatures recorded between humus and mineral soil are of academic interest, but they do not concern the stored-seed problem since it is fairly established that this layer is outside the zone of tree-seed storage.

In order to determine more directly the effect of the temperatures recorded, western pine seeds were actually sown prior to the fire in two of the tests. The temperatures which they experienced are indicated in Table 3. In a medium burn not a single seed survived. In a light fire, where only the top half of the duff was scorched, only two germinations were obtained out of 1,000 seeds originally sown. This

one experiment strengthens the implication of the others that, except in isolated cases on light burns western white pine seed cannot survive fires.

Coincident Dissemination

It is rather remarkable how much the subject of coincident dissemination has been neglected in the research work in the western white pine type. Despite casual observations of Brewster (2) and Larsen (9), no serious thought was given to this method of providing seed for regenerating an area until the past two years. And yet it may be the most important of the three methods of seed dissemination.

In establishing permanent sample plots following the severe fires of 1926, the most startling result obtained in the first year was the incontrovertible evidence of the vast amount of reproduction which could have come only from coincident dissemination. The figures for the reproduction on five of such areas are given in Table 4. The two areas with the least reproduction had previously been burned or logged and bore only a small number of seed trees previous to the fire. All of the reproduction, varying from 500 to 575,000 seedlings per acre, must of necessity be attributed to the seed shed the same fall

as the fire upon fresh ashes. For the duff was completely consumed down to mineral soil, and with it all stored seeds must have perished. As for subsequent dissemination the germination recorded in the spring of 1927 was, of course, uninfluenced by any seed shed after the dispersal of 1926.

TABLE 4

GERMINATION ON ONE-YEAR-OLD BURNS FROM SEED SHED IMMEDIATELY AFTER FIRE

Species	Number of Seedlings Per Acre First Spring After Fire					
	Plot 133	Plot 130	Plot 129	Plot 132	Plot 131A	Plot 131B
White Pine	11,434	151	1,375	1,640	208	0
Western Larch	10,548	424	22,092	5,660	750	250
Douglas Fir	581	30	0	820	83	0
White Fir	5,887	1,485	1,000	280	0	0
Red Cedar	329,516	24,394	0	9,000	83	0
Western Hemlock	206,613	11,212	167	2,900	250	83
Engelmann Spruce	10,320	91	4,377	380	1,167	167
Totals	574,899	37,787	29,011	20,680	2,541	500

Plots 133 and 129 were fully stocked stands. Plot 130 had as a seed source the seed trees left on a typical timber sale. Plot 132 was on a light 1910 burn from which a 10 per cent stocking survived. Plot 131 depended on seeding from the side for its seed source. Subplot A was within 400 feet of green timber, while subplot B was 400 to 800 feet away. The fires which burned all these areas occurred in July and August, 1926.

Another indication of the importance of coincident dissemination was furnished by the seed-coat study at Tillicum Creek, previously mentioned. Here again there was not a bit of evidence that a single seedling came from stored seed, and an overwhelming attestation of the fact that coincident dissemination was responsible for the reproduction.

Larsen's (15) study of single and double burns supports this same idea. He found after single burns that the reproduction was generally prompt, uniform and complete. In the case of double burns it was almost invariably deficient. The apparent reason was that on single burns there was ample coincident and early subsequent dissemination from the trees which eventually died as a result of the fire, but bore cone crops for several years. On the other hand, the double burns had few or no trees left to provide reproduction following the second torrefaction.

The plan of screening quadrats in front of going fires or logging operations should help to place more definitely the importance of coincident dissemination. In this study one set of quadrats will be screened before either fire or logging. In these the only possible seed source will be stored seed. The second set of quadrats will not be screened until the crop of seed ripening the autumn

immediately succeeding the fire or operation has been shed. These quadrats will show both stored and coincident seed. The third group of quadrats will not be screened at all and will get their reproduction from all three sources. A quantitative study of the amount of seed found in these three types of quadrats should furnish us with a fairly close idea of the relative importance of the three major sources of dissemination.

Subsequent Dissemination

Of all the forms of seed dissemination, the subsequent is of most vital concern in timber-sale practice. If stored seed and coincident dissemination are sufficient to restock an area adequately, the expensive necessity of leaving seed trees may be obviated. The true importance of seed trees should be indicated quite conclusively by the screening experiment just described.

If, as seems probable, seed trees really are necessary, there are a number of factors which must be determined. First comes the question of the amount of seed produced, which has already been discussed in the second section of this report. Another very important matter is the distance of effective dispersal. Here we have both empirical and experimental evidence. Studies made by Brewster (3) in 1912 and 1913 covering 30 large clear cuttings and burns, on which all

dissemination had to come from the outside, gave fairly adequate information on the effective distance of white pine seed dispersal. Attacking the matter from a more fundamental viewpoint, Isaac (8) released seeds from kites and pilot ballons at different heights and in different wind velocities. Comparing Isaac's figures of dispersal after release in an 8-mile wind from a height of 150 feet with Brewster's empirical examination, surprisingly close correlation is found as indicated in Table 5. The reasons why Issac's work indicates a much greater dispersal beyond 1,200 feet than does Brewster's is because most of the seeds at the further end of dispersal are unfertile and consequently do not show up in the reproduction.

TABLE 5

PERCENTAGE OF WHITE PINE SEED OR REPRODUCTION WITHIN GIVEN DISTANCES FROM SOURCE OF DISPERSAL

Distance Feet	Percentage Found Within Given Distances	
	Seed Isaac's Experiment°	Reproduction Brewster's Examination
0 - 200	39	40
201 - 400	14	23
401 - 600	24	14
601 - 800	8	11
801 - 1000	2	7
1001 - 1200	3	4
1201+	10	1

° Height of release of seed 150 feet; wind velocity 8 miles per hour.

Three other northern Rocky Mountain species were also released in a wind of 8 miles per hour from a height of 150 feet. The per cent of seed recovered at various distances from the source of dispersal is shown in Table 6. Isaac (8) also made some tests with pilot balloons in wind velocities too light for the use of kites. Since these very light velocities are the most common ones during the period of dissemination, his figures are worth reproducing, and are shown in Table 7.

TABLE 6

DISTANCE OF SEED DISSEMINATION OF DOUGLAS FIR, HEMLOCK, AND CEDAR

ISAAC'S EXPERIMENT

Distance Feet	Per Cent of Seed Found Within Given Distances		
	Douglas Fir	Western Hemlock	Western Red Cedar
0 - 200	10	41	92
201 - 400	15	15	8
401 - 600	56	40	
601 - 800	14	1	
801 - 1000	2	2	
1001 - 1200	1	0	
1201+	2	1	

Height of release 150 feet; wind velocity 8 miles per hour.

TABLE 7

DISTANCE OF SEED DISSEMINATION IN LIGHT WIND VELOCITIES

Distance Feet	Percentage of Released Seed Found Within Given Distances		
	Western Yellow Pine	Western White Pine	Douglas Fir
100	10	12	1
200	22	30	2
300	60	46	14
400	84	64	27
500	98	76	60
600	100	90	82
700		95	97
800		99	100
Wind Velocity in Miles per Hour:	3.5	2.2	3.6

Height of release, 150 feet.

It has just been mentioned that very light wind velocities are most common during the period of dissemination. This statement is not based on mere dogmatism, but upon the actual evidence of 13 years of wind measurements at the Priest River Experiment Station, which is in the heart of the western white pine type. From the records, shown in Table 8, it appears that winds of 11 miles per hour or more only occur about 5½ hours in any year during the period of western white pine seed dispersal which is, roughly speaking, September and October. The maximum velocity ever obtained was only 18 miles per hour. This makes it unnecessary to consider such high velocities as 23 miles an hour, which Isaac studied. A further analysis should be made of the relation between wind velocity and amount of dispersal since it is barely possible that a larger share of the seed may be disseminated during the 5½ hours of high wind than during the remaining 1458½ hours when the velocity is 10 miles or less.

TABLE 8

WIND VELOCITIES AT THE PRIEST RIVER EXPERIMENT STATION DURING SEED DISSEMINATION

Wind Velocity Miles Per Hour	No. Hours Occurring Each Sept. & Oct.	Wind Velocity Miles Per Hour	No. Hours Occurring Each Sept. & Oct.
6	26	13	1
7	17	14	½
8	9	15	½
9	6	16	0
10	3	17	0
11	1½	18	½
12	1½	Total	66½
		Total Under 6 Miles	1,397½

A recent study for determining the distance of seed dispersal has involved the laying out of seed traps on completely denuded areas at regular intervals from the edge of the nearest live timber. By collecting the seed at regular periods and running germination tests on them, it should be possible to determine the effect of distance on the amount and viability of the seed shed.

Other very important matters to be determined, in the event that seed trees are necessary for adequate reproduction, are the windfirmness and fire resistance common among the species of the western white pine type. In regard to windfirmness, we have no experimental data. As a tentative statement of this characteristic, however, a group of men familiar with the silviculture of the white pine forests were asked to rate the 10 indigenous species in order of windfirmness. The composite result of their rating is shown in Table 9.

TABLE 9

WINDFIRMNESS OF TREES OF THE WESTERN WHITE PINE TYPE

1. Western Larch
2. Western Yellow Pine
3. Douglas Fir
4. Western Red Cedar
5. Western White Pine
6. Lodgepole Pine
7. Western Hemlock
8. Lowland White Fir
9. Alpine Fir
10. Engelmann Spruce

This rating is a composite of the individual ratings of H. R. Flint, Elers Koch, J. A. Larsen, Robert Marshall, Philip Neff, D. S. Olson, R. H. Weidman, W. W. White, and M. H. Wolff. The most windfirm tree is placed first.

Flint (5), in 1925, made a very interesting theoretical rating of the fire resistance of these same 10 species, basing his views on such characteristics as thickness of bark, root habit, resin content of bark, branching habit, stand density, inflammability of foliage, and lichen growth. Recent analysis by the Experiment Station of fire damage on a couple of areas burned over in 1926, gives a remarkably close check of Flint's theoretical rating. On one of these areas the mortality two years after the fire coincided perfectly with Flint's rating. On the other area just one species, hemlock, was out of place. These results are shown in Table 10.

TABLE 10

RELATIVE FIRE RESISTANCE OF TREES FOUND IN THE WESTERN WHITE PINE TYPE

Flint's Theoretical Rating	Percentage of Mortality Found 2 Yrs. After Fire			
	Flat		East Slope	
Western Larch	Western Larch	2	Western Larch	5
Western Yellow Pine	- - -		- - -	
Douglas Fir	Douglas Fir	22	Douglas Fir	55
Lowland White Fir	Lowland White Fir	73	Western Hemlock	56
Lodgepole Pine	Lodgepole Pine	78	Lowland White Fir	58
Western White Pine	Western White Pine	79	- - - -	
Western Red Cedar	Western Red Cedar	86	Western White Pine	80
Engelmann Spruce	Engelmann Spruce	95	Western Red Cedar	85
Western Hemlock	Western Hemlock	100	Engelmann Spruce	88
Alpine Fir	Alpine Fir	100	Alpine Fir	95

IV

GERMINATION

Perhaps the first point to be considered in discussing the effect of germination on reproduction is the germination per cent which may be obtained under most favorable conditions among the different seeds of the western white pine type. We have no final information on the subject, but certain greenhouse tests conducted by Planting and the Experiment Station during the past 15 years have yielded figures of tentative value. These are shown in Table 11. They indicate in general a much higher germination for the pines, Engelmann spruce, red cedar, and Douglas fir than for the true firs and larch.

TABLE 11

GERMINATION PER CENTS OBTAINED IN DIFFERENT TESTS
For Tree Species Found in the Western White Pine Type

Western White Pine	Western Yellow Pine	Douglas Fir	Engelmann Spruce	Red Cedar
55	55	51	53	80
55	53	37	51	79
54	53	27	38	76
54	44	18	38	59
47	41	15	27	38
41	35		24	
41	33			
40	32			
36				
33				
32				

Western Larch	Lowland White Fir	Alpine Fir
30	23	2
21	5	

Tested by the Savenac Nursery and the Northern Rocky Mountain Forest Experiment Station.

The results of controlled field tests conducted by Larsen (12) show a very interesting variation in germination on different surfaces. The first tests, made in 1913, included white pine, yellow pine, Douglas fir, larch, hemlock and cedar. They indicated that burned and denuded areas have a distinct advantage for germination and survival when compared with those surfaces on which the duff is undisturbed.

In the second tests, started in 1918, 4-feet square plots on seven different surfaces were sown with 2,000 western white pine seeds each. The results are presented in Table 12. This table also indicates that burned or denuded surfaces are very much more favorable for germination than undisturbed ones.

TABLE 12

GERMINATION BY DIFFERENT SURFACES - CONTROLLED EXPERIMENTS

Surface	Germination Percentage for Different Species			
	Western White Pine 1918	Western White Pine 1920	Western Larch 1920	Engelmann Spruce 1920
Mineral Soil	61	24	13	35
Partly burned duff	59	--	--	--
Charcoal and ashes	39	--	--	--
Ashes	33	24	20	24
Rotten wood	13	--	--	--
Unburned duff	10	2	4	14
Charcoal and partly burned duff	10	--	--	--

Note: Date after species name refers to autumn in which seeds were sown.

The third series of tests, commenced in 1920, bears out the findings of the earlier ones. Ashes and bare mineral soil showed a much higher percentage of germination than did duff, for all three species sown. These were: western white pine, western larch, and Engelmann spruce. The figures for this experiment are also shown in Table 12.

These tests indicate the superiority of mineral soil for germination under the limited conditions which were studied. But a great amount of further work is needed in order to determine the effect of different sites and years on survival. There are so many variables in this problem that it will presumably have to be finished in the laboratory where the effect of climate and site can be eliminated and a much greater variety of precise conditions obtained than is possible in the field.

The results of the controlled experiments have been rather strikingly substantiated by the examination of 62 milacre quadrats on the Tillicum Creek plot. Here all surfaces were exposed to a prolific dispersal of white pine, larch, white fir, cedar and hemlock seed during the autumn of 1926. It may be safely assumed that the amount of seed shed on all surfaces was practically equal. But the germination

showed tremendous variation, with all the denuded surfaces giving far better germination than the undisturbed ones. Table 13 brings out this characteristic very forcibly. Similar results were obtained from two other plots on which it is unfortunately impossible to give such concise figures. All these records check the controlled experiments of Larsen, and indicate very clearly a superiority for burned and denuded surfaces as seed beds.

TABLE 13

REPRODUCTION BY DIFFERENT SURFACES

TILLICUM CREEK SAMPLE PLOT

Surface	Number of Germinations Per Acre First Year After Fire		
	White Pine	Western Larch	White Fir
Mineral soil	12,730	15,233	8,679
Charcoal	10,667	4,000	---
Partly burned duff	10,455	11,304	1,196
Rotten wood	6,111	1,667	556
Unburned duff	3,540	531	1,062

Seeds shed autumn of 1926; germination up to August 1, 1927.

The greatest number of seedlings ever found on a single milacre in the western white pine type is probably worth noting, although of no practical or scientific value. On one .001 acre quadrat at Tillicum Creek, there were found a total of 3,284 seedlings which figure if maintained would mean 3,284,000 seedlings per acre. These were principally cedar and hemlock. The highest figure yet obtained for western white pine on 1003 quadrats has been 41 seedlings on a milacre.

V

SURVIVAL

This section must be prefixed with the unsatisfactory statement that our knowledge is entirely inadequate. The best way of approaching the scant evidence which we possess is to consider the theoretical factors influencing survival. These are:

1. Light
2. Moisture
3. Temperature
4. Chemical nature of soil.
5. Physical nature of soil.
6. Diseases

All the information on the subject of survival will be considered under these heads.

Light

The only information in regard to the effect of light on reproduction is observational in character. It is presumed that there is a point at which light becomes so scant as to preclude reproduction. This deduction is made from the fact that in virgin stands no regeneration of any except the most tolerant species survives. Even here it is a question whether this lack of reproduction is due to lack of light, to root competition, or to the influence of diseases like damping-off fungus.

Certain studies by Haig on old timber sales are destined to bring out the effects of different intensities of shade on the reproduction eventually surviving, but it is questionable whether such studies, made long after the death of seedlings has taken place, will yield the positive results desired. Permanent sample plots seem to offer a more encouraging possibility, particularly if actual instrumental measurements are made of the sunlight reaching the quadrats.

It seems quite probable, however, that the final method of solving this problem will have to take place in the laboratory, where seeds can be sown under precisely similar conditions and submitted artificially to varying intensities of light. Such work would be similar in nature to the experiments conducted by Bates (1) at the Rocky Mountain Experiment Station.

Moisture

Of all the factors governing the survival of reproduction in the western white pine type, the most vital appears to be moisture. Of all the factors affecting moisture, none is more important than the aspect on which a given site is located. Larsen (12) has obtained some interesting figures on the moisture found on opposite sites. These figures are shown in Table 14. They indicate that north aspects are far more favorable to reproduction than southerly exposures. This conclusion has been checked empirically by Haig (7) in his study of

cutover areas. An examination of four old timber sales on the Coeur d'Alene and Kaniksu Forests showed from 2 to 25 times as much reproduction on north as on south exposures.

TABLE 14

EFFECT OF ASPECT ON PHYSICAL FACTORS OF SITE

Aspect	Surface Temperature		Surface Soil Moisture		6-12" Soil Moisture	
	Ave.	Max.	Ave.	Min.	Ave.	Min.
Northeast	60.2	85.0	43.6	10.7	42.9	11.9
Southwest	76.9	125.0	7.7	0.5	14.6	2.6

Based on daily records for August, 1913; 1915; and 1916.
Sites exposed to full sunlight.

The next point which should be considered in connection with moisture is the topographic situation. In this case hollows and lower slopes are generally much wetter than upper slopes and ridge tops, and this is clearly reflected in the reproduction. For instance, Larsen (13) found the following number of seedlings per acre on different parts of the 1910 Trail Creek burn on the Coeur d'Alene Forest: upper slope, 84; middle slope, 131; lower slope, 181. Observationally, Larsen's results have often been checked by everyone familiar with the western white pine type.

Larsen's (12) study of the effect of soil surface on survival shows conflicting results. In one test in which he sowed seeds on different surfaces, the natural areas showed much better survival, while in the other the denuded surfaces gave the higher survival figures. The two-year records which he obtained are shown in Table 15.

TABLE 15

SURVIVAL BY DIFFERENT SURFACES - CONTROLLED EXPERIMENTS

Surface	Percentage of Seeds Germinating Which Survived Two Years Later			
	Western White Pine 1918	Western White Pine 1920	Western Larch 1920	Engelmann Spruce 1920
Partly burned duff	100	--	--	--
Unburned duff	97	58	35	0
Ashes	96	94	36	64
Charcoal and ashes	62	--	--	--
Rotten wood	53	--	--	--
Mineral soil	48	--	64	67
Charcoal and partly burned duff	36	--	--	--

Note: Date after species name refers to autumn in which seeds were sown.

In the future, very interesting results should accrue from the permanent sample plots where every seedling which germinates is staked with a pin and followed until it dies or becomes completely established. With 1003 quadrats on which seedlings are staked in such a manner, we should soon develop some sound conclusions. As yet, these plots are too young to be of value in this connection.

Another important factor affecting moisture is the shade cast by standing trees, down logs and underbrush. That standing trees have a marked influence in preserving soil moisture has been brought out by Larsen's (12) study of the effect of timber on the physical factors of site. His work illustrates strikingly the unfavorable meteorological effect which a large clearing exerts on the establishment of seedlings. His results are shown in Table 16.

TABLE 16

EFFECT OF TIMBER ON PHYSICAL FACTORS OF SITE

Stand Conditions	Max. Air Temp.	Min. Air Temp.	5 P.M. Humidity	Evaporation	6" Soil Temp.	6" Soil Moisture
Open	87.7	39.5	30.7	35.3	63.2	34.2
1/3 Cover	85.3	44.3	33.0	26.9	59.9	25.8
Uncut	80.3	46.2	35.0	16.0	54.7	30.3

The beneficial effect of brush on preserving site moisture may be deduced from Larsen's (13) study of several old burns on the Coeur d'Alene Forest. He found very little survival from germination which took place the first two years after fire. Thirteen years after the conflagration only six per cent of all the reproduction on the ground dated to the two initial years. Since there is no reason to suppose any smaller germination at that time, and since furthermore there was an exceptionally good seed crop the year following the burns, it is a natural inference that the lack of protecting brush the first two years made life on those denuded sites exceedingly precarious for the delicate seedlings.

Much more conclusive in this regard is an unusually neat experiment performed by Wahlenberg (17). He planted yellow pine seedlings directly under Ceanothus bushes, at the outer edge of the shrubs and entirely removed from their influence. His conclusion is worth quoting:

"During dry summer weather in western Montana, it was found that under Ceanothus brush atmospheric evaporation was less, relative humidity greater, soil temperature lower, and soil moisture greater in amount than in adjacent open spaces. As a result of such conditions it was also found that survival of western yellow pines during their first dry season following field planting was much higher under the bushes than in the open."

While trees and brush are probably in general beneficial to the survival of reproduction due to the shade which they furnish, it is also true that they sometimes have a deleterious effect due to root competition. Here again there are no adequate figures to present but it is hoped to instigate some trenching experiments in which all root competition from the outside will be cut off. By comparing the results obtained on such quadrats with those on check areas, some light should be thrown on the importance of root competition on reproduction.

Finally, and above all else in connection with moisture, comes the effect of meteorological conditions. It would be hard to imagine anything more striking than the enormous amount of reproduction which occurred in the white pine type in 1927, because the good seed year of 1926 was followed by an unusually moist year. For instance, although the survival on two Experiment Station sample plots was only 50 seedlings per acre for the years of 1925 and 1926, in 1927, it suddenly jumped to 31,825 seedlings per acre. On another plot, the reproduction for 1926 was only 230 seedlings per acre and after 1927 it had increased to 10,800 seedlings. This was, of course, partially due to poorer seed years in 1924 and 1925, but primarily to the fact that those two years were exceedingly

dry, while 1927 was the wettest in the 17-year history of the Priest River meteorological station.

In this same connection, it seems logical to suggest that the reason why better reproduction was obtained on the earlier timber sales in the western white pine type than in the more recent ones was due to a series of relatively wet years from 1911 through 1916. Nine of the 10 years following 1916 were exceedingly dry and this must have had a very unfavorable effect on the survival of reproduction. Without any permanent sample plots it has been impossible to check this hypothesis.

Since precipitation plays such an important part in determining the survival of reproduction, it is reasonable to suppose that there are certain distinct precipitation limits for different forest types. The records of those weather stations in the northern Rocky Mountain region which have been running for two-thirds or more of the past 15 years, indicate a very close relationship between the average annual precipitation and the timber type as shown in Table 17. From this it appears that white pine requires from 28 to 40 inches of annual precipitation. However, this figure must not be taken too seriously for the scant distribution of stations throughout the western white pine type and the climatic fluctuations combine to make it quite probable that the true extremes are not indicated.

TABLE 17

RELATION OF PRECIPITATION TO FOREST TYPES

Type	Station	Mean Annual Precip.	Type	Station	Mean Annual Precip.
Grass-Yellow Pine transition	Dayton	13.48	Western White Pine	Trout Creek	28.52
	Spokane	13.85		Priest River	28.84
	Victor	14.22		Kellogg	30.29
	Como	14.70		Avery	31.38
	Plains	15.08		Heron	31.72
	Polson	15.98		Musselshell	37.28
				Wallace	38.80
Western Yellow Pine	Libby	16.35			
	Porthill	17.53	White Pine-larch Transition	Haugan	27.60
	Thompson Falls	20.19		Belton	27.99
	Kamiah	20.53			
	Coeur d'Alene	23.08	Larch-Douglas Fir	Fortine	17.30
	Potlatch	23.66		Upper Yaak	19.28
	St. Michaels	24.88		Columbia Falls	20.10
	Orofino	26.50	Lodgepole Pine	Yellowstone Park	17.13
				Redlodge	19.03
Yellow Pine-White Pine transition	St. Maries	23.74			
	Sandpoint	27.68		Alta	19.16
				Hebgen Dam	24.16
			Grass-Lodgepole transition	Helena	13.50
				Philipsburg	15.07

cambium of young seedlings. Indirectly such temperatures, of course, help very greatly to dessicate the soil.

Similar to the precipitation ranges found in the different types in the northern Rocky Mountain region are the temperature ranges which the various meteorological stations manifest. In this case the extreme average figures for the western white pine type vary from 42° to 46°. As in the case of precipitation, these figures probably do not represent the complete range for the western white pine type, but they seem worth presenting in Table 18.

TABLE 18

RELATION OF TEMPERATURE TO FOREST TYPES

Type	Station	Mean Annual Temp.	Type	Station	Mean Annual Temp.
Grass-Yellow Pine transition	Spokane	48.2	Western White Pine	Avery	46.0
	Plains	45.2		Kellogg	45.4
	Como	45.0		Wallace	44.7
	Polson	45.0		Heron	44.5
	Victor	44.0		Trout Creek	43.7
	Dayton	43.9		Priest River	42.5
				Musselshell	---
Western Yellow Pine	Orofino	49.8			
	Coeur d'Alene	47.6	White Pine-Larch transition	Belton	42.4
	St. Michaels	45.4		Haugan	41.0
	Thompson Falls	45.0			
	Potlatch	44.8	Larch-Douglas Fir	Columbia Falls	42.8
	Libby	44.5		Fortine	41.2
	Porthill	44.3		Upper Yaak	40.6
	Kamiah	---			
			Lodgepole Pine	Redlodge	39.9
Yellow Pine-White Pine transition	St. Maries	47.2		Yellowstone Park	38.7
	Sandpoint	44.9		Alta	37.6
				Hebgen Dam	34.8
			Grass-Lodgepole transition	Helena	43.5
				Philipsburg	41.4

Chemical Nature of Soil

Marshall and Averill (16), in a recent study of soil acidity, found in 58 cases out of 60 a neutral to alkaline reaction on the surface of one-year-old burns. Since the surfaces of forest soils are normally acid, it seems probable that this alkalinity on severe burns may reduce the survival of reproduction. A few years of rainfall probably leaches out a great deal of this alkalinite and that may be one reason why Larsen (13) found that although very little reproduction which germinates in the first two years after conflagrations survives, thereafter it comes in abundantly on single burns. This subject is one which requires further investigation.

Aside from this scant information on hydrogen-ion concentration, our knowledge of the chemical nature of the soil is entirely deficient.

Physical Nature of Soil

Nothing at all is known about the relation of the physical character of the soil to seedling survival in the western white pine type.

Diseases

Although there are many fungi in the western white pine type which do a great amount of damage to older trees, there are few species which attack seedlings. The

damping-off fungi may kill a great deal of reproduction but we have no adequate data on the subject. The rust Pucciniastrum pustulatum, which has for its alternate host the fireweed, shrivels up and kills white fir seedlings. With the advent of the white pine blister rust it is anticipated that a much gloomier picture of reproduction diseases will have to be painted.

Unlike the eastern white pine, the western white pine type is cursed by no serious insect diseases that attack reproduction. However, the older trees suffer heavy loss from the ravages of the mountain pine beetle, Dendroctonus monticolae. This insect causes especially serious damage among trees which have been weakened by fire. In many cases such trees might recover if it were not for the work of this secondary enemy. Burns also afford ideal breeding conditions for this bark beetle, and consequently bad fire years have often been followed by serious beetle epidemics.

SUMMARY

Those conclusions which in the present status of the reproduction study appear probable will be summarized. They rest on a foundation of experimental data but in few cases is this adequate to preclude a reasonable possibility of error. Nevertheless, it seems desirable to present these tentative beliefs both as a basis for future investigation and as an aid to administrative men in this Region who find that information may be useful even though not final.

Seed Production

1. Dominant and codominant trees produce practically all of the western white pine seed. Suppressed trees produce none.

2. The girdling of hemlocks definitely stimulates seed production.

3. Starting with 1911, good white pine seed years have come regularly at three-year intervals.

Seed Dissemination

1. There is little evidence to indicate that seed stored more than one year is of much importance in reproducing the white pine forest.

2. A one-year holdover of white pine seed is perfectly normal and this may have an important bearing on reproduction following logging.

3. Stored seed cannot survive severe or medium burns and only in sporadic instances does it come through even a light fire.

4. Coincident dissemination, or in other words dissemination during or immediately after fire or logging, is a very important source of reproduction which has been largely overlooked in past investigations.

5. From 90 to 100 per cent of all the viable western white pine seed falls within 800 feet of the seed tree.

6. The tentative rating of the important trees of the western white pine type in regard to windfirmness is: western larch, western yellow pine, Douglas fir, western red cedar, western white pine, lodgepole pine, western hemlock, lowland white fir, alpine fir, Engelmann spruce.

7. The tentative rating of the same species in regard to fire resistance is: western larch, western yellow pine, Douglas fir, lowland white fir, lodgepole pine, western white pine, western red cedar, western hemlock, Engelmann spruce, alpine fir.

Germination

Denuded surfaces are more favorable than natural ones for the germination of all the species of the western white pine type.

Survival

1. Of all the factors affecting the survival of reproduction in the western white pine type the most important is moisture.

2. North aspects are far more favorable to the survival of reproduction than southerly exposures largely because of this greater moisture.

3. Similarly lower slopes are more conducive to survival than upper ones.

4. The shade of standing trees and brush has a marked influence on conserving soil moisture.

5. The meteorological conditions obtaining at any period exert the greatest influence on soil moisture and therefore on survival.

6. There have been regular wet and dry cycles for at least 250 years in the western white pine type.

7. The soil alkalinity on fresh burns may have a deleterious effect on the establishment of reproduction.

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